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EFFECT OF CERTAIN NOISES UPON

DETECTION OF VISUAL SIGNALS

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# EFFECT OF CERTAIN NOISES UPON DETECTION OF VISUAL SIGNALS

A

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas in Partial Fulfillment

of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY



By

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Austin, Texas

January, 1963

## ACKNOWLEDGMENTS

The contributions of others to the accomplishment of this dissertation have come from many persons, and in so many ways, that there can be no hope of recognizing here more than a fraction of them.

Professor Charles S. Watson provided indispensable answers to technique and instrumentation questions at numerous stages of research planning. Dr. Donald E. Robinson, Mr. Mayo Grantham, and Mr. Irwin Hafter all participated actively in the procurement, assembly, calibration, and/or maintenance of the experimental apparatus.

Professor Lloyd A. Jeffress, besides serving as patient teacher and understanding committee member, furnished extremely valuable counsel and arranged the loan of several essential components of the apparatus from resources of the Defense Research Laboratory, The University of Texas.

Heinz Gaylord, Allan Simmons, Irwin Thacker, and Mickey, George, and Cheryl Latham served as unpaid subjects, making their donations of much-demanded time stand out amid a considerable amount of volunteer assistance. Dr. J. F. Schmidt and Dr. Roy MacDonald also deserve particular mention for their personal contributions of time and ideas.

The United States Air Force made possible pursuit of graduate study, including preparation of this dissertation, through the Civilian Institutions Program of the Air Force

Institute of Technology (Air University). Assistance and support from USAF resources on the campus were cheerfully provided by personnel of The University of Texas Detachment, Air Force Reserve Officer Training Corps (Air University).

The generous assistance of all those mentioned is gratefully acknowledged, as are the gifts of those not named.

Special and separate thanks must be expressed to the Dissertation Committee Chairman, Professor Robert K. Young, for the abundant material support and continuing intangible help (including but not limited to advice and encouragement) which he provided.

Finally, the writer would like to make explicit the fact that possession by his wife, Mary Ellen, of more confidence in his eventual success than he himself felt at any point in his academic endeavors was an important factor contributing to the realization of the current educational goal.

Austin, Texas
December 17, 1962

W. H. W.

TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER 1

## INTRODUCTION

Since Urbantschitsch (1888) first reported observation of the interaction of vision and hearing, interest in the effects of stimulation of one human sense upon sensitivity in other modalities has alternately flourished and subsided.[1] The modest number of studies reported since 1948 has been essentially of two varieties: (1) objective in method and negative in findings, and (2) subjective, yielding some positive results.

A tendency on the part of authors to treat the sense modalities as though fundamentally discrete has been noticed by Bartley (1958). The present writer has found widespread indication, in the literature of perception and attention, that the _inhibitory_ potentiality of some noises and sounds, with respect to perception via senses other than hearing, is generally recognized. This cannot be said with regard to sounds acting in the _facilitatory_ direction. Reluctance on the part of authors to grant serious attention to intersensory facilitation is understandable, in view of the absence of a substantial experimental literature dealing with this topic.

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[1]Only those aspects of sensory interaction study relevant to effects of sounds upon visual sensitivity will be developed in this study.

The few modern studies which have produced clear, positive findings of facilitation have employed response measures tending toward the introspective, such as critical flicker frequency (CFF) and perceived brightness. Value and cost factors ('biases') confound with sensitivities when such techniques are employed (Swets, Tanner, & Birdsall, 1961). Extensive studies by Chapanis, Rouse, and Schachter (1959), Inaba (1957), and Maier, Bevan, and Behar (1961) have produced negative data with regard to facilitation.

Reference will be made later to other studies employing human subjects. Let us look now, however, at some pertinent findings from animal studies.

Intersensory suppression of on-going cortical activity in unanaesthetized cats has been observed, using permanently implanted electrodes (Hernandez-Peón, 1961). Visual, tactual, and olfactory stimuli were employed as stimuli "distracting attention" for repetitive sounds. The interaction was ascribed in that and similar animal distraction research to the efferent nerve fibers from the reticular formation of the lower brain stem.

Various sensory electrophysiological studies, by such workers as Granit, Hartline, Ratliff, and Eccles, have built up an imposing fund of information regarding inter-neuronal inhibition and disinhibition at the receptor element and low-order neuronal levels. Understanding of the central processes in relation to these mechanisms is increasing steadily. Buser and Imbert (1961) have studied interaction via polysensory cells of the motor cortex. Fessard (1961) describes observation of "interactive" responses by cells in the reticular formation and other areas to external stimuli.

Chapter 8 of Hartmann's (1935) book provides summary coverage of the main channel of intersensory study up to the time of the book's preparation. Subsequent literature, as well as the material reviewed by Hartmann, was reviewed by Ryan (1940). Gilbert (1941) reviewed the literature on sensitivity variations due to "auxiliary" stimuli. Between those two, the survey coverage of sensory interaction works to that time was exhaustive. Most of the studies from the ensuing 13 years were done in the USSR, under the leadership of S. V. Kravkov. In an extensive review, London (1954) relates the substance of the Russian research on sensory interaction. London's compilation is of notable value, since only a tiny portion of the reports of work in this area by USSR psychologists appears in the English language sources.

Essential points regarding a number of studies in the area of this investigation are given in Table 1. Arbitrary response measure categories are employed, into which the studies listed do not all separate unequivocally.

Ogilvie's (1956) auditory flutter - CFF study is reported in considerable detail and has been useful in the formulation of the framework of this investigation. The salient findings of Ogilvie's investigations are quoted:

Table 1

Representative Researches on Effects of Auditory Stimulation upon Functions of Primarily Visual Character

Category I: Flicker/CFF as Response Measure

| Worker(s) | Visual Stimulus | Auditory Stimulus | Reported Findings |
|---|---|---|---|
| Schiller (1932) | black-white disk rotating | beating tones | flicker sensation increased |
| Allen & Schwartz (1940) | variety of filtered lights | tones | oscillation of sensitivity; some facilitation and some depression |
| Grignolo, Boles-Carenini, & Cerri (1954) | interrupted light | 55 to 85 db. tones, 2 to 4 KC | increased CFF, foveal and peripheral |
| Ogilvie (1956) | white flashes from glow-mod. tube | 80 and 90 db. SPL auditory flutter <u>in</u> and <u>180° out of</u> phase <u>re. flicker</u>; also contin. noise | very slight rise in CFF with <u>in-phase</u> flutter (significant at 1% level) |
| Maier, Bevan & Behar (1961) | White and colored lights | 40 and 80 phon tones at 3 frequencies | a few complex, "hi-order interaction" relations significant. Maximum difference 4% between conditions |

Category II: Comparisons and Matchings

| Worker(s) | Visual Stimulus | Auditory Stimulus | Reported Findings |
|---|---|---|---|
| Strozecka (1940) | curved line figure + adjacent gray <u>to match</u> | 775 cps. at 70-75 db. SL; continuous over 8-15 min. of visual work | sound facilitated strong visual contrast and inhibited weak |
| Maruyama (1957) | standard light | 80 phon tones of 100 & 2,000 cps. just preceding light | brightness increased by high tone; reduced by low tone |

| Worker(s) | Visual Stimulus | Auditory Stimulus | Reported Findings |
|---|---|---|---|
| Gebhard & Mowbray (1959) | white flicker | flutter | subjectivity observed that flutter "drives" flicker; reverse not so |
| | Category III: Visual Acuity/Color Perception | | |
| Urbantschitsch (1888) | details not reported | details not reported | sounds sharpened sensitivity to light |
| Tanner & Anderson (1896) | colored glass patches | T-fork tones; "whiTT" | sounds facilitated sensations, mostly by attention effects |
| Newhall (1923) | 5 mm. square of paper, viewed tachistoscopical'y | click, simultaneously with visual stimulus onset | clicks raised sensitivity via attention effects |
| Hartmann (1933) | separated squares | 180 and 2,100 cps. "loud" | sound raised acuity |
| Kravkov (1934) | separated squares | tones | sound facilitates if black object is on white ground; inhibits if white object is on black ground |
| Serrat & Karwoski (1936) | patches of spectral light | loud 410 cps. tone | no change in sensitivity |
| Bogoslavski & Kravkov (1941) | white and colored lights | aircraft engine noise | some facilitation and some depression |
| Burnham (1941) | white squares; flicker; color fields | 775 cps. at 60 db.SL | no effects due to sound on acuity, CFF, or retinal color fields, i.e. no interaction between modalities |
| Chapanis, Rouse & Schachter (1949) | devices for: 1. dark adaptation 2. contrast sensitivity 3. form discrimination | 3800 cps.(70 db.) 2800 cps.(30 db.) | sounds had no effects |

Table 1 (continued) 

| Worker(s) | Visual Stimulus | Auditory Stimulus | Reported Findings |
|---|---|---|---|
| Inaba (1957) | Landoldt rings | noise, and 7 pure tones, up to 80 db. SL | no interaction; some sound influence on perceptual lng. rates |
| | Category IV: Reaction-Time in Discrimination Tasks: Other Perceptual Tasks | | |
| Wapner, Werner, & Chandler (1951) | luminous rod in dark room | 800 cps. 11 db.; via earphones set into headrest | subjective verticality shifted to side opposite tone |
| Mowbray (1954) | short phrases | simultaneously, short phrases | subject could not successfully divide attention on task |
| Klemmer (1956) | 3 small lights | tone requiring discriminatory response; presented at time separate from lights | time-sharing lengthens reaction-time |
| Adams & Chambers (1962) | 1/2 in. diameter red, white, green lights | 3 pure tones, + complex info-bearing auditory error-correcting mixture | if stimulus events are certain, bisensory responding is superior to unisensory. When events are uncertain, impairment is inferred for bisensory responding |
| Hershenson (1962) | light from glow-mod. tube at 2 luminances | 50 msec. pulses of white noise at approximately 70 and 90 db. SL | facilitation; and as a function of amount of asynchrony. Reducing light intensity diminished facilitation, but reducing sound intensity had no effect |

1. CFF was higher with in-phase flutter than with out-of-phase auditory flutter; the difference is significant at the 1% level.

2. CFF was not changed significantly by stimulation with continuous noise.

3. CFF in the presence of interrupted noise was higher than with continuous noise, the difference being significant at the 1% level.

4. None of the effects tested varied significantly with brightness or with intensity of noise.

The method of study of effects of noise upon vision used for this experiment departed from Ogilvie's working method in these basic respects:

a. Flutter and light flash rates were fixed, not undergoing constant decrease.

b. Intensity was not studied as a variable of the experiment.

c. Light levels were far above the low intensity ranges used by Ogilvie.

d. There were neither CFF nor method-of-limits involvements in the response measure employed.

A representative study from Category II of Table 1, the flicker and flutter rate matching experiments reported by Gebhard and Mowbray (1959), is pertinent in the present context. There is similarity to this research in that auditory flutter and a flashing light amid an illuminated field were employed as stimuli for trained Os. Gebhard and Mowbray reported greater accuracy of intra-sensory rate matching than of cross-sensory matching, the "driving" effect mentioned in Table 1, and other findings.

Among many dissimilarities, the Gebhard and Mowbray work cited differs most conspicuously from the research here reported in its research objective. Gebhard and Mowbray wished to ascertain whether a "sensory compromise" between auditory and visual modality accuracy functions would be reached if cross-sensory matching of rates were attempted. This experiment inquired as to the effects of noise stimuli upon visual sensitivity (as manifested in visual signal detection performance). Much of the apparent similarity is superficial.

Had facilitation of visual thresholds been observed by Inaba (1957), the mediating mechanism(s) might have been likened to the one(s) involved in this experiment. Inaba permitted 1.5-sec. observations of visual targets, with auditory stimuli commencing .5 sec. prior to target presentation onset. The cessation of both stimuli was simultaneous. White noise, as well as pure tones, was employed in the "auxiliary" modality, with amplitudes graded to an 80-db. SL maximum, as mentioned in Table 1.

The "acuity family," represented by Inaba's investigations, and including no studies with decisive findings of acoustic facilitation among the four principal works done since 1934, is that family to which the present experiment is most nearly related.

Before comparing the qualities of the present experiment to a study from the remaining category included in Table 1, a digression to the realm of unisensory signal detection is in order. Tanner and Swets (1954) reported early application of their statistical theory of signal detection to the area of visual sensitivity research. Results of experiments they carried out in that connection have, in turn, been cited in reports further elaborating their theory of perception as a "detection" process (Swets *et al.*, 1961). Several other descriptions of the theory are also available (*e.g.* Licklider, 1959, pp. 52-76; Pollack, 1961).

The theory of signal detection holds that many classical psychophysical methods are defective due to assumptions they imply regarding the existence of high thresholds and of chance-factor determination of responses to "sub-threshold" stimuli. The theory places great emphasis upon the role of non-sensory factors in determining responses in "yes-no" situations. The alternative-interval, forced-choice method is lauded by virtue of its immobilizing of the "criterion," in turn a product of "value and cost" considerations. The theory conceives of the detection function in terms of overlapping normal distributions of probability densities along a likelihood ratio axis, with *O* selecting a "noise alone" or "signal plus noise" response, depending upon whether the likelihood ratio for Observation *i* locates itself on the "noise alone" or the "signal plus noise" side of the criterion. "False alarm" responses in "yes-no" situations result from location of the criterion within the "noise alone" distribution.

The forced-choice signal detection model for determination of visual sensitivity was chosen for this experiment principally because neutralization of bias was desirable -- *i.e.* the factors Swets *et al.* label "non-sensory" were considered potentially contaminating. Signal detection necessarily involves decision processes. Signals can be highly detectable, but when (as in this case) it is not the absolute value of the signal, nor its separation from "noise alone," but, rather, the comparative detectability of a given signal under various experimental "auxiliary" conditions that is of interest, one prefers signals of such energy that "signal plus noise" overlaps "noise alone" to a substantial extent.

Hershenson (1962) used two "well-practiced" *O*s in a reaction-time measurement situation involving single 50 msec. bursts of white noise at amplitudes comparable to that employed in this experiment. His visual stimulus could hardly be regarded as similar to that used in this study because of its comparative enormity. Probably a more crucial difference between the two studies under consideration is again related to response processes. Hershenson's experimental task was the familiar depression of the single telegraph key, based upon perception of a signal. *O* responded to light and/or a noise by the same movement. With "signal strength" in both modalities probably far outside practical limits of the "noise alone" distributions, the detection ("decision") function of the S-O-R complex would appear slight in Hershenson's experiment.

Harris (1950) looked at several reaction-time studies. He concluded that cross-sensory facilitation expressed as shorter reaction-times depends upon summation of presynaptic discharges upon motoneurons, and stands apart from facilitation of sensory acuity, where "attention" phenomena are involved.

Both CFF and detection of flashing light signals in visual noise can be regarded as having to do with the resolving power of the visual mechanism. To test the superiority of auditory flutter over steady noise (found in Ogilvie's CFF experiment), a comparison was made between those two types of noise stimuli in the present study. Interruption of noise on another level was included as an obvious corollary to the alternative-interval, forced-choice visual presentation pattern: Both types of noise (flutter and steady noise) were (separately) timed to occur on a continuous basis and, on other occasions, only while the alternative observation intervals were in progress.

Specific predictions regarding the relative or absolute effects of noises upon the dependent variables were not advanced. The method employed for this research was considered promising of exposing sensory interaction effects.

## CHAPTER II

## METHOD

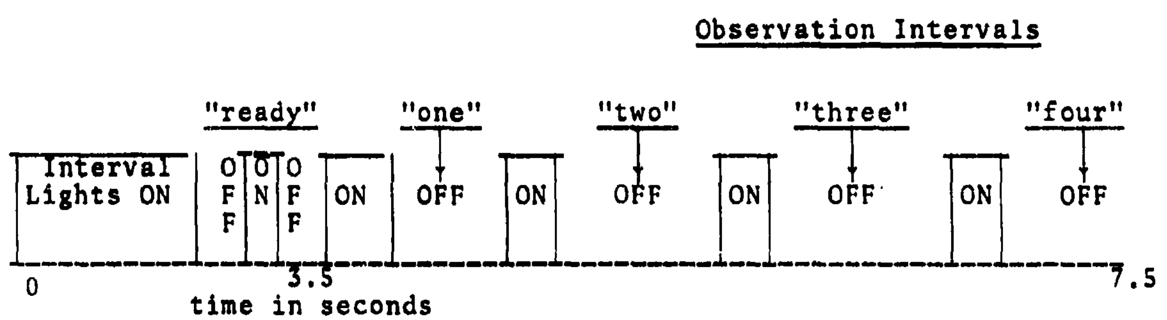
Six trained *Os* were tested for visual detection performance for 1200 trials, while experiencing controlled auditory input via earphones. A description of the *Os*, the apparatus, and the procedure may be found in Appendix A. Briefly, *O* looked at an illuminated circular field and compared, for each of four short observation intervals, the appearance of the centermost spot of the field. He reported on a four-alternative-interval, forced choice basis, stating which interval was marked by a faint, blinking, centered, light signal.[1]

The experimentally presented sound was random noise of moderate amplitude (approximately 75 db. $SPL_{oa}$), either steady or interrupted to produce auditory flutter. A 2 x 2 experimental design was afforded by the steady vs. flutter noise types ($T_1$ and $T_2$), and by provision for passage of either noise type into the earphones either continuously during trial sequences ($P_1$) or only during the four observation intervals of each trial ($P_2$). Thirty trials under fixed conditions constituted a "run," the duration of which was 3.75 min. All runs were separated by rest

[1]Responses were recorded directly upon moving tape by *O*. See Appendix A.

periods of at least 2 min. Usually, eight runs (two under each of the four noise conditions, randomly sequenced) constituted the 1-hr. testing session.

Regardless of whether noise was presented with the observation intervals or continuously through the run, the intervals were identified for O by the following sequence of lighting of 1-1/2 in. x 2-1/2 in. frosted lucite panels positioned at the top and bottom of the cylinder end of the viewing tube.[2] Illumination of each of these panels was provided by a 6-w. incandescent lamp (miniature), having a clear glass bulb.




Determination of Observation Intervals by Lights

Each O was individually oriented and trained on the detection

[2]See Appendix A for explanation of the parts of the apparatus mentioned.

task.[3] Training consumed between 7 and 11 (typically 9) 1-hr. sessions. Forty experimental runs were then accomplished by each O.

Training experience and performance for the investigation proper were distributed among the four noise conditions (see below) equally.

The conditions used, based upon a 2 x 2 manipulation of noise type and mode of presentation, were: steady noise, continuously ($T_1P_1$); steady noise, with intervals ($T_1P_2$); flutter, continuously ($T_2P_1$), and flutter, with intervals ($T_2P_2$).

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[3]Factors considered in determining the point at which training could be considered sufficient included stabilization of performance around a moderate level at some aperture, E's prognostications, based upon experience with Os of prior experiments of a similar sort, and practical details relating to the conditioning of the apparatus and available subject time.

CHAPTER III

# RESULTS

The number of correct identifications of the signal interval among the 30 trials constituting the run was used as the score unit. Scores for 40 runs per *O* (6 *O*s used), divided equally among the 4 conditions, and obtained in 8-run sets (2 runs of each condition, randomly ordered) comprised the experimental data. Table 2 presents the results of an analysis of variance of the 240 scores. Table 3 lists the mean scores by *O* and by condition. Figure 1 depicts means by condition for the five successive sets for all *O*s. Figure 2 gives graphic indication of the relationships among the presentation modes and noise types in general.

For this group of *O*s, visual signal detection under the conditions of the experiment was superior when noise was presented simultaneously with the observation intervals to performance under continuous noise presentation conditions. No other variable was found significant, nor were there any significant interactions. The magnitude of the difference between the $P_1$ and the $P_2$ means was 3.30 correct interval identifications per run for the group; one *O* (ES) averaged more than seven points higher on $P_2$ runs[1] than on $P_1$ runs. Five of the six *O*s had higher $P_2$ than $P_1$ means.

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[1]Significance tests were not performed for any differences among scores of individual *O*s.

Table 2

Analysis of Variance Summary

| Source of Variance | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Between Os (O) | 1,477.871 | 5 | | |
| Noise Presentation Mode (P) | 650.096 | 1 | 650.096 | 7.58* |
| Noise Type (T) | 1.504 | 1 | 1.504 | .17 |
| Run Sequence (R) | 367.837 | 9 | 40.871 | 1.65 |
| O x P | 428.479 | 5 | 85.696 | |
| O x T | 44.871 | 5 | 8.974 | |
| O x R | 1,115.838 | 45 | 24.796 | |
| P x T | .504 | 1 | .504 | .35 |
| P x R | 68.946 | 9 | 7.661 | .91 |
| T x R | 60.538 | 9 | 6.726 | .68 |
| O x P x T | 7.171 | 5 | 1.434 | |
| O x P x R | 378.229 | 45 | 8.405 | |
| O x T x R | 444.837 | 45 | 9.885 | |
| P x T x R | 63.704 | 9 | 7.078 | .99 |
| O x P x T x R | 322.371 | 45 | 7.164 | |
| Total | 5,432.796 | 239 | | |

*Significant beyond the 5% level of confidence.

Table 3

Table of Mean N Correct
(in runs of 30 trials)

| Observer | $T_1P_1$ | $T_2P_1$ | $T_1P_2$ | $T_2P_2$ | $P_1$* | $P_2$* | $T_1$ | $T_2$ | Total |
|---|---|---|---|---|---|---|---|---|---|
| BY | 17.1 | 17.1 | 15.9 | 16.5 | 17.1 | 16.2 | 16.5 | 16.8 | 16.65 |
| HG | 11.9 | 9.8 | 17.0 | 16.1 | 10.8 | 16.5 | 14.4 | 12.9 | 13.70 |
| ES | 13.3 | 14.6 | 20.8 | 21.4 | 13.9 | 21.1 | 17.0 | 18.0 | 17.52 |
| MB | 20.1 | 20.2 | 21.6 | 22.4 | 20.2 | 22.0 | 20.8 | 21.3 | 21.07 |
| JS | 16.0 | 17.3 | 20.3 | 21.3 | 19.6 | 21.5 | 20.7 | 20.4 | 20.55 |
| JG | 19.7 | 19.5 | 21.7 | 21.3 | 19.6 | 21.5 | 20.7 | 20.4 | 20.55 |
| Total | 16.35 | 16.42 | 19.55 | 19.80 | 16.38* | 19.68* | 17.95 | 18.11 | 18.03 |

*Presentation mode difference of 3.30 significant beyond the 5% level.

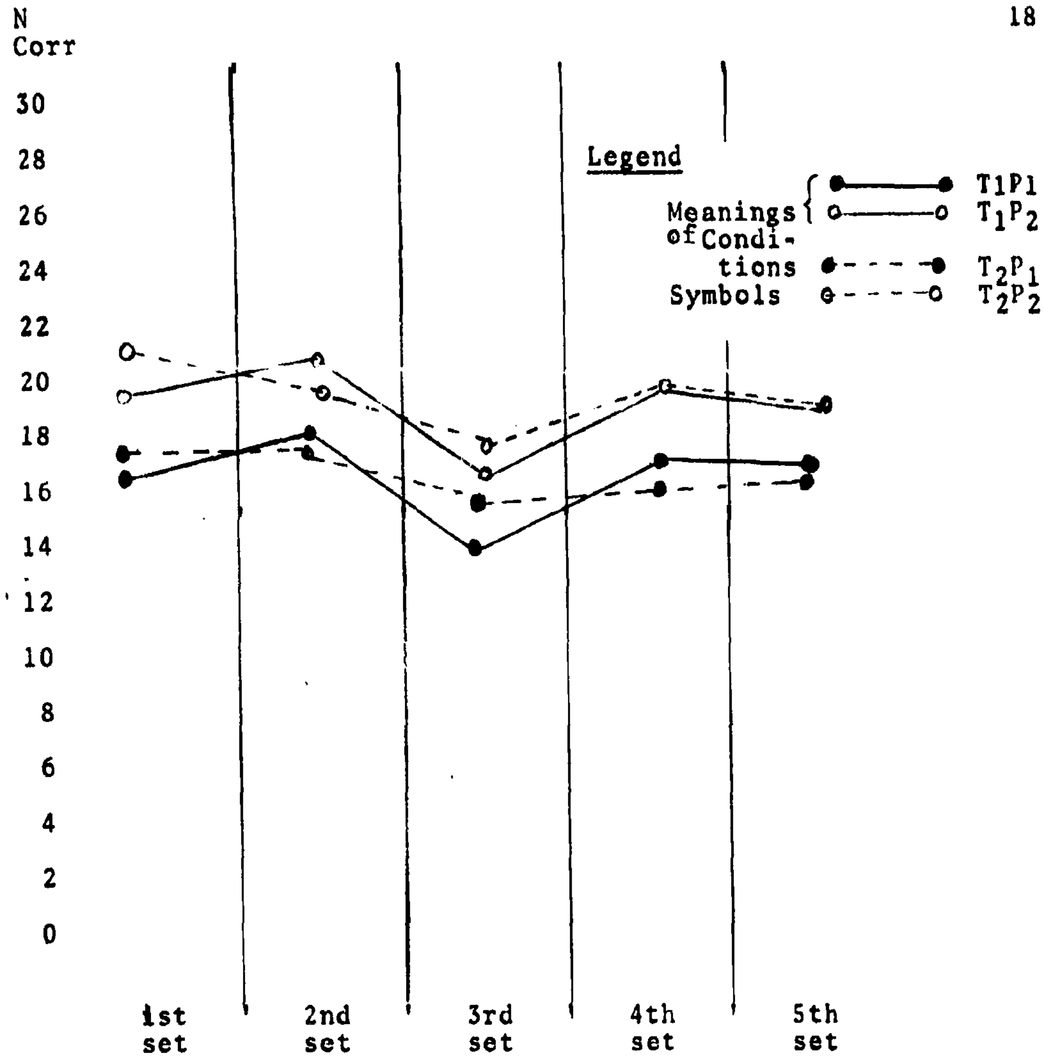


Figure 1

Mean Scores by Sets

(Each point represents 2 runs per O, i.e. 12 scores/point.)

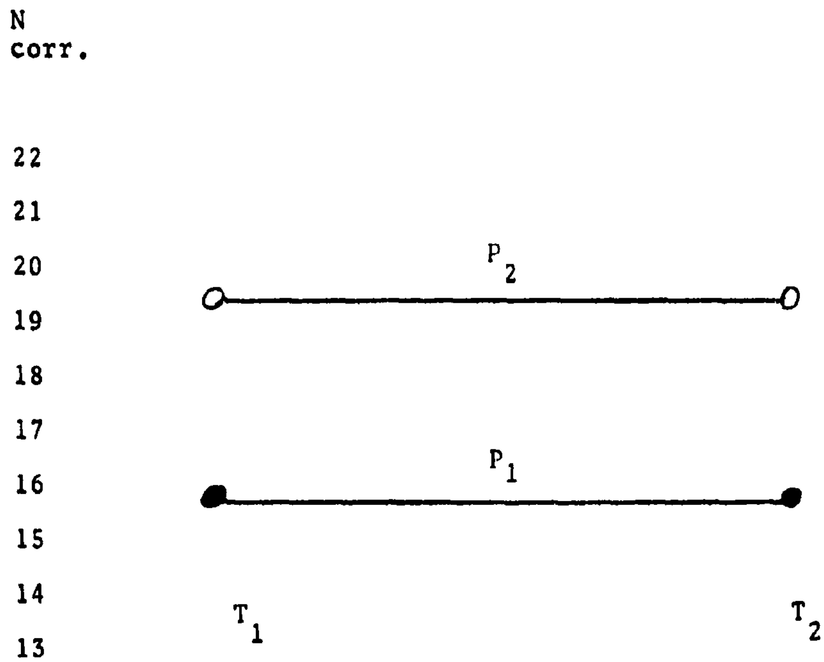


Figure 2

It has been assumed that the O variable in this study was properly a random one. The O x P mean square was consequently used as the error-term for testing the significance of the main effect P. (The proper error-term in a "mixed model" is the next higher term which includes the variable being tested, along with the random variable.) In this analysis, the O x P term was the second largest mean square. If any other of the terms were used to test the significance of the P effect, F would be greater than that obtained using O x P.

It may be contended with some validity that Os were a selected group, pre-screened by occupation, age, and other qualifications for the positions they occupied. If it be supposed that these considerations preclude the treatment of O as a random variable, then the proper error-term for all significance tests in the purely fixed model which would remain is O x P x T x R. With 45 df, that term has a mean square of 7.16.

It cannot be conclusively resolved that O was a random variable in the study. If it actually were a fixed variable, the significant difference observed is represented by an F score many times greater than that shown in Table 2, with reliability of the difference increased commensurately.

# CHAPTER IV

## DISCUSSION

Presentation of 75 db. SPL noises concurrently with the observation intervals[1] _facilitated_ detection of visual signals, in relation to control condition performance.[2] This facilitation averaged 3.30 correct responses per $P_2$ run, representing 20 per cent improvement in performance over the $P_1$ mean of 16.38. Maier _et_ _al_. (1961), having surveyed the CFF changes attributable to sound-induced facilitation, assessed the "maximal shift" obtained at about 10 per cent. They class their own significant double and triple interaction effects ("Loudness x Wave Length" and "Frequency x Loudness x Wave Length") at the 2 - 4 per cent shift magnitude with Ogilvie's (1956) "Flutter vs. Continuous Noise" effects. Maier _et_ _al_., terming such sensory interaction _hetermodal_ _influences_, found it extremely difficult to comment upon their own findings in physiological terms, and decided that these phenomena are conceptually obscure.

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[1]That is, the $P_2$ presentation mode.

[2]The doubtfulness of any inhibitory noise effects is shown below.

Licklider (1961) has noted that several regions of the brain could participate in interactions of the audio analgesia sort. He stresses, along with other physiological principles, the point that facilitation is focalized, while inhibition is diffuse.

Aside from any other site of potential cross-modality neural interaction, it is known that the reticular formation possesses the properties appropriate to the mediation of intersensory facilitation and inhibition. Stimulation of the superior portion of the reticular formation of the brain stem has been found to produce facilitatory effects upon motor activity and neuronal discharge rates, while the bulbar end of this region is principally inhibitory (Lindsley, 1951). Hernandez-Peón (1961, p. 515) describes this area _in toto_:

> . . . a region where impulses of all modalities converge . . . . the same region . . . is able to decrease or increase the excitability of most sensory neurons, and thus to inhibit or facilitate sensory transmission at all the levels of the specific afferent paths . . . . control is tonic and selective.

This investigation was concerned with the issue of whether or not stimulation through one receptor system, _i.e._ hearing, could be observed to modify the sensitivity of other sense modalities (_e.g._ visual efficiency). Whether or not the reticular formation be, in fact, the sole functional agent involved in the interaction which was observed remains an unanswered question, beyond the scope of the research task undertaken; nonetheless, a most intriguing matter for contemplation and future investigation is presented.

In the interpretation of C. S. Watson,[3] $P_2$ noises in the present experiment functioned as additional time cues to O, conveying information regarding "when to look for the signal." There is substantiation for that view in the verbal reports of the Os, which were consistent with a concept of limited "attending power," able to be most efficiently brought to bear in the detection task when the peripheral interval lights were augmented in their separation function by $P_2$ noises. (A survey of the scores of the 240 experimental runs indicates that intervals were clearly separated, primarily by the interval light, under $P_1$ conditions: One O achieved her highest score on a $T_1P_1$ run and another scored as high on a $T_1P_1$ run as on her highest $P_2$ run.) The classical "temporal span of attention" (Woodrow, 1951), "the maximal physical time over which may extend a temporal stimulus pattern, the successive parts of which are perceived as a whole, possessing a unitary property of duration," may well have relevance to the verbally reported benefits of $P_2$ noises, based upon introspection in conscious experience. This, however, was an empirical study; the introspective exploration avenue was not pursued. Rosenblith (1961) has remarked, in this connection, that there has been a paucity of current advances in our under-

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[3]Personal communication.

standing of foundations for time perceptions. It is suggested that cross-modality time cues may, under conditions such as those employed in the present study, weigh more heavily than cues within the same modality. Unfortunately, the research accomplished gives no evidence with which to evaluate the efficacy of the interval lights.

The findings of the present study further suggest that considerable attention to control of heteromodal impingements which do not convey hints as to correct intervals would be in order for all experimentation using alternative-interval choice as a response measure. That is, mere absence of systematic relation to test signal does not assure the neutrality of an "extraneous" stimulus.

After considering the results of many industrial and laboratory studies of the effects of noises on work production, accuracy, and reaction-times in "vigilance" situations, Broadbent (1958, pp. 96-97) was led to describe the effect of a noise as similar to that of blinking. His paradigm for "attention," applied to this topic, centers the sensitivity of an all-sensory "filter" upon an "active channel." His filter possesses a "bias" toward channels conveying information regarding stimuli which are intense or consist of high frequency sound. Broadbent also assigns to the filter a bias toward channels previously quiet, thus depressing the chances of information carried on busy channels reaching the perceptual system. He terms the latter bias that for "novel stimuli."

Now, internal blinking is supposed to occur on a continual basis, but be subject to a certain degree of direction in situations which have times more suitable than others for the blinking to occur. The filter figuratively snaps to another channel, then returns to its previous state when blinking occurs during a task. Apparently, certain classes of sounds are capable of prompting more frequent blinking, which can result in distraction with consequent impairment of performance on some tasks.

An application of Broadbent's filter theory is that regardless of the blink-producing quality of a sound, having periods that O could depend upon as "quiet" in the task-information channel would shortly obviate detrimental effects of familiar sound stimuli, because the blinking would be conducted during those periods. Broadbent's survey of experimental literature confirmed his expectation that there would be no persisting impairment due to noise when "predictable safe periods" were included.

The same author gives first prominence to the provision of "safe periods," then adds avoidance of frequencies over 2 Kc at intensities over 90 db. to the conditions recommended for industrial protection against undesirable (inhibitory) effects of noises.

Audio analgesia (Licklider, 1961) can be likened to the type of noise effect studied by Broadbent. The analgesic power of white noise at intensities up to 116 db. SPL may be regarded as equivalent to "locking the filter onto the insistent channel."

This experiment employed noise that shared only one fragment of its physical character with the type of noise believed capable of depressing task performance: Noises used did include frequencies between 2 and 3 Kc.

Broadbent (1958, p. 90) saw several examples of lack of effect when noise was either below 90 db. or when predictable safe periods were available. He states the innocuousness of noises below 90 db. to have been found in all investigations.

Because none of the auditory stimuli was "novel" (Os having been exposed to all noises extensively during training), because "predictable safe periods" were profuse, and because noise amplitude was carefully monitored and held at approximately 75 db. SPL, it is considered most improbable that the experimental noises exerted depressant or inhibitory effects upon detection performance on any experimental runs in this study. If it be assumed, nevertheless, that a chronic depression did prevail, caused by the noises, then one is confronted with the odd fact that the noise inhibited significantly less when presented only with the observation intervals than when continuously present. Any form of reconciliation of this with a "blinking-during-noise" concept seems remote. Disregarding the filter theory, empirical findings of other research would suggest greater inhibitory potential (facilitatory potential not being considered, for the moment) in an interrupted than in a continuous noise.

## CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

In this study, alteration of the mode of presentation of auditory stimuli of moderate intensity was found to exert a marked influence upon visual signal detection performance by a group of human subjects. The effect is regarded as a facilitatory variety of sensory interaction and is greater in terms of performance improvement magnitude (percentage) than that characteristic of CFF experimentation involving heteromodal facilitation.

Ten-burst per second auditory flutter (in positive synchrony with light signal when present) produced effects not substantially different from steady white noise effects.

The superior detection condition was that in which noise accompanied the alternative observation intervals, as distinct from continuous noise presentation. The neural mechanism mediating this interaction is possibly similar to that observed in implanted cat brain studies showing heightened neuronal responses to given sensory stimuli as functions of heteromodal stimulation, or electrical stimulation of nervous tissue ~~(see p.2)~~. This experiment does not permit assignment of any locus for the central or peripheral neural correlates of the overt behavior.

The notion of efferent sensitization, of the "arousal response" sort, would accommodate the results obtained. Perhaps some unknown time-perception-mediating mechanism operated independently of "efferent sensitization" to take advantage of the increased "when-to-look" cues furnished by "with intervals" noises.

Further studies should be conducted to answer the following questions raised by this investigation:

1. What are the relative efficacies of interval separation lights and "with intervals" auditory cues in alternative-interval visual signal detection?

2. What effects would follow from temporal and intensity dimension variations of noise presentation in visual signal detection?

3. Would "with intervals silence" (the "reciprocal" of $P_2$ condition used) exert effects upon detection?

4. Would auditory flutter at other than rates of 10 per sec., synchronized with light signal flash rates, prove superior to steady noise in the visual detection situation for trained Os at any flutter/flash frequency?

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# APPENDICES

# APPENDIX A

## DESCRIPTION OF OS, APPARATUS, AND PROCEDURES

### Os

The four female and two male Os averaged 23 yr. of age (ranging from 15 to 37). Four wore eyeglasses, and one (E.S.) claimed severe hearing loss monaurally. The females were receiving wage compensation as employees of the Psychology Department in various capacities. One male was a graduate student who served as an unpaid volunteer. The other male was paid a small, fixed sum, agreed upon in advance of the experiment.

### Apparatus

A "Detection of Light Flash in Noise" ("Dolfin") arrangement was used, consisting of the following principal components:

1. Model PS 2A Photo Stimulator (Grass Instrument Co.).

2. Sixteen-inch diameter cylinder, constructed in the Department workshop, of sheet metal, plyboard, glass, and including four standard lighting sockets, with lamps and wiring, plus variable aperture wheel behind the glass at back and miniature lamps at front for interval separation (see below). The interior of the cylinder was painted white.

3. Viewing tube, shaped from wire mesh and poster board, and covered with cloth. A leather and rubber oscilloscope viewer was adapted to permit comfortable viewing of the target from the distance of approximately one meter.

4. A holder and floor stand for the cyliner.

5. A tablet arm chair was equipped with a motor-operated tape winding system, accommodating rolls of 3-1/2-in. wide graph paper. O recorded item-by-item responses by pushing one of four buttons (spring-supported, with points on bottoms), causing a hole to be made in the tape corresponding spatially to the chosen alternative for that trial. The tape was hand-scorable with a perforated key.

6. Control gear. This consisted of (1) the Photo Stimulator less its lamp and reflector portion - these being secured to the cylinder mentioned above - (2) a Grayson Stadler electronic switch that served as noise amplifier, noise gate when Flutter condition was employed, and as the source of external electrical pulses for operating the Photo Stimulator in synchrony with the Flutter; (3) an 8 r.p.m. motor-driven cam mechanism with three cam disks moving three microswitches. (The electronic switch was the property of Defense Research Laboratory.)

7. Webster "Royal" Tape Recorder, with 1200 ft. of Ampco tape on which had been recorded the output of a white noise generator, passed through a 100-3,000 cps. filter.

8. Permoflux PDR-20 Earphone outfit, loaned by Defense Research Laboratory.

9. A Voltmeter (Defense Research Laboratory property) was used to monitor the input electrical equivalent of the proper acoustic power output of the earphones.

Figure 3 summarizes the apparatus and the principal interconnections.

## Procedure

By closing his master switch, E turned on the four 75-w. incandescent Sky Blue lamps inside the cylinder that produced visual noise. Simultaneously, the response record tape was passed under the four selection buttons at O's fingertips, and the cam drive motor operated the three cam disks at the rate of 1 cycle every 7.5 sec. E turned the tape recorder on "play" to provide noise, and placed the recorder output lead in the "continuous" or the "with intervals" connector, depending upon whether the run was $P_1$ or $P_2$, respectively. He further set the appropriate "gate" and Photo Stimulator switches for the Steady or Flutter type noise. After checking the voltmeter for correct noise amplitude, E instructed O to "BEGIN." O watched the center of the sand-blasted glass target and responded by depressing the chosen recording button at the conclusion of the cycle (i.e. trial), the choice dependent upon which of tho four observation intervals was decided upon as the one most likely to have been the one during which there occurred a small flashing signal in the center of the target. O also called out to E the interval punched for each trial. E had depressed the Stimulus lever just prior to the correct interval and released it just after same. E had a written sequence for the correct

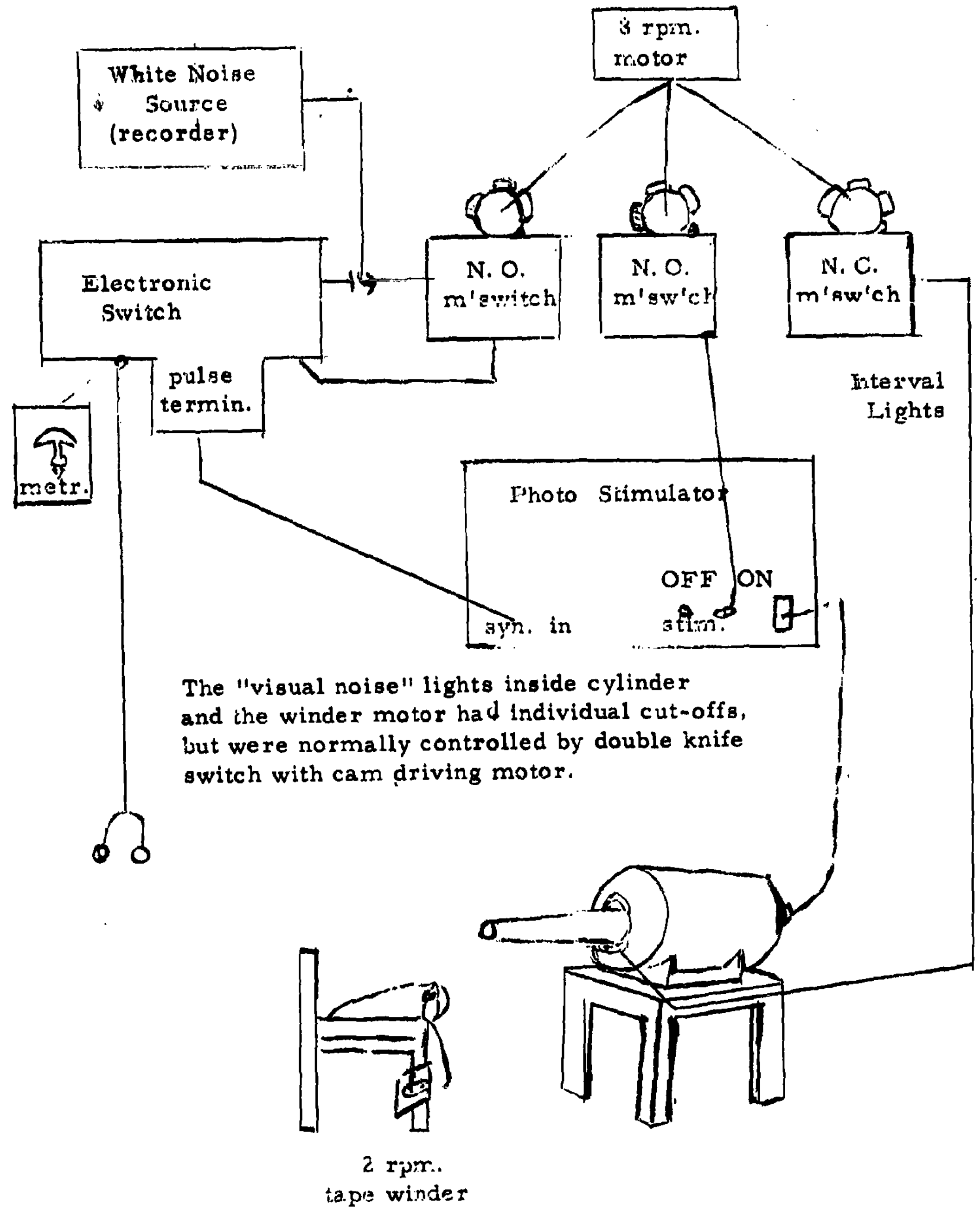
3 rpm.
motor
White Noise
Source
(recorder)
Electronic
Switch
N. O.
m'switch
N. O.
m'sw'ch
N. C.
m'sw'ch
pulse
termin.
metr.
Interval
Lights
Photo Stimulator
OFF
ON
syn. in
stim.
The "visual noise" lights inside cylinder
and the winder motor had individual cut-offs,
but were normally controlled by double knife
switch with cam driving motor.
2 rpm.
tape winder

Figure 3

stimulus intervals for all runs prepared in advance of testing. He noted O's oral response beside the corresponding trial's correct interval, but did not talk to O at any time during the run. E's turning off of the master switch at the end of the run informed O that he should relax for the rest between runs. E started the mechanical clock for the predetermined rest interval, counted the preliminary score for the run, and advised O of it, drew a pencil line along the button block on the response tape, and made any appropriate changes in the noise condition and/or the visual signal aperture to fulfill the requirements for the run to follow. O was not informed of the moment of transition from training to the experimental block of runs until after the final session.

Additional Comments

Flashes and intervals. Each discharge of the photo stimulator caused a small dot of flashing blue-white light to be transmitted to O's (sandblasted) side of the glass target field. Detection of this signal, amid blue-white visual noise, was rendered optically more or less difficult by the size of the circular hole, positioned in the center of the direct light path, with all other possible avenues of signal light passage from lamp unit to O's eyes effectively blocked. The aperture positioned in the pass-through spot, then, was the signal intensity setting. The four observation intervals of each trial were timed at approximately 440 m.sec. each. At a flash rate of nominally 10 per sec., there were usually five flashes during each (correct) observation interval. Flash duration is represented by the Grass Instrument Co. (1956) to be fixed at 10 microseconds, independent of frequency and other parameters; the persistence of the visual image, however, caused the 10 per sec. rate to be approximately equivalent to a 50 per cent on-off ratio.

Noises. The Photo Stimulator emits a substantial level of distinctive sound energy with each flash of light. Even if this were not so, there were other intra- and extra-experimental acoustical factors that would justify following the examples of Broadbent (1958) and Stevens *et al*. (1941) by using a "quiet" or control condition of steady white noise at a sound pressure level of 75 db. over-all, heard binaurally by *O* via earphones.

*Vexierversuche* (called "ESP Runs"), wherein the optical aperture setting was zero, were used to assure that the acoustical component of the lamp flash was entirely neutralized for *O* by this noise. *Continuous, steady noise* was just mentioned. A simple relocation of the "GR" plug on the noise source output lead, passed the electrical equivalent of the noise through a cam-operated microswitch, only while closed by the cams determining the four observation intervals. Thus, the *Steady Noise with Intervals* was available. *Auditory Flutter* was substituted for steady noise, in either mode of presentation, by the operation of the multivibrator component of the electronic switch. These electronic elements were adjusted to open and close the switch proper on a 50-m.sec. open - 50 m.sec. closed basis. When the steady noise condition was desired, this "gating" feature was by-passed (by the turning of a knob) and the switch was constantly closed (the "gate" was open). The amplifier/attenuator elements of this device are usable on either setting. Auditory Flutter was first described and named by Miller and Taylor (1948), used in sensory interaction research by Ogilvie (1956), and studied at length by Gebhard and Mowbray (1959) and Mowbray, Gebhard, & Byham in 1956.

Synchronization. The cams of the three cam disks, which were secured onto a common shaft extending from the 8 r.p.m.motor, were aligned in as precisely uniform an arrangement as could be managed with the aid of a dual-track oscilloscope, pairing two of the micro-switch circuits on the two beams. When one of the auditory flutter noise conditions was used, the Photo Stimulator was switched off of its own flash rate control system and was triggered by the positive pulse originating in the multivibrator elements of the electronic switch. Since the "gate" was opened for noise by the positive pulse also, there was apparently near-perfect positive synchrony of the onset of each of the noise bursts constituting the auditory flutter, with a flash of the lamp unit, assuming all switches were closed.

Visual noise field. O was presented with a circle of brightly illuminated glass, having a flat texture, which was computed to be equivalent to a monocular visual angle of approximately 10°. (At

1 meter, the field had a diameter of about 17 cm, as viewed by either eye.) The luminance of the field measured 625 foot-lamberts from O's face location.

## APPENDIX B

## OBSERVATIONS

JS
Training Runs

| Run No. | Aperture | Cond. | No. corr. | Run No. | Aperture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 1 | 51 | $T_1P_1$ | 12 | 6 | 51 | $T_1P_2$ | 19 |
| 2 | | $T_2P_1$ | 13 | 7 | 51 | $T_2P_2$ | 13 |
| 3 | | $T_1P_2$ | 12 | 8 | 51 | $T_1P_1$ | 8 |
| 4 | | $T_2P_2$ | 22 | 9 | 51 | $T_1P_2$ | 20 |
| 5 | 51 | $T_2P_1$ | 12 | 10 | | Void | |
| 11 | 51 | $T_1P_1$ | 12 | 15 | 51 | $T_2P_2$ | 18 |
| 12 | | $T_1P_2$ | 14 | 16 | | $T_2P_2$ | 14 |
| 13 | | $T_2P_1$ | 16 | 17 | | $T_2P_1$ | 11 |
| 14 | | $T_1P_1$ | 13 | 18 | | $T_1P_2$ | 12 |
| 19 | 50 | $T_2P_1$ | 16 | 23 | 50 | $T_2P_2$ | 25 |
| 20 | | $T_1P_1$ | 19 | 24 | | $T_2P_2$ | 29 |
| 21 | | $T_1P_1$ | 21 | 25 | | $T_2P_1$ | 20 |
| 22 | | $T_1P_2$ | 23 | 26 | | $T_1P_2$ | 24 |
| 27 | 50 | $T_2P_1$ | 16 | 31 | 50 | $T_1P_1$ | 29 |
| 28 | | $T_2P_1$ | 16 | 32 | | $T_2P_2$ | 29 |
| 29 | | $T_2P_2$ | 25 | 33 | | $T_1P_2$ | 23 |
| 30 | | $T_1P_1$ | 21 | 34 | | $T_1P_2$ | 28 |
| 35 | 50 | $T_2P_2$ | 30 | 39 | 50 | $T_2P_1$ | 28 |
| 36 | | $T_2P_1$ | 23 | 40 | | $T_1P_1$ | 27 |
| 37 | | $T_1P_1$ | 30 | 41 | | $T_1P_2$ | 30 |
| 38 | | $T_2P_2$ | 29 | 42 | | $T_1P_2$ | 28 |
| Experimental Runs | | | | | | | |
| 43 | 51 | $T_2P_1$ | 20 | 47 | 51 | $T_2P_2$ | 24 |
| 44 | | $T_2P_2$ | 23 | 48 | | $T_2P_1$ | 20 |
| 45 | | $T_1P_1$ | 17 | 49 | | $T_1P_2$ | 21 |
| 46 | | $T_1P_2$ | 15 | 50 | | $T_1P_1$ | 12 |
| 51 | 51 | $T_1P_1$ | 16 | 55 | 51 | $T_2P_2$ | 26 |
| 52 | | $T_1P_1$ | 21 | 56 | | $T_2P_1$ | 13 |
| 53 | | $T_2P_2$ | 17 | 57 | | $T_2P_1$ | 19 |
| 54 | | $T_1P_2$ | 20 | 58 | | $T_1P_2$ | 23 |

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 59 | 51 | $T_1P_1$ | 7 | 63 | 51 | $T_1P_1$ | 12 |
| 60 | | $T_2P_1$ | 12 | 64 | | $T_1P_2$ | 18 |
| 61 | | $T_2P_2$ | 15 | 65 | | $T_2P_2$ | 16 |
| 62 | | $T_1P_2$ | 16 | 66 | | $T_2P_1$ | 19 |
| 67 | 51 | $T_1P_1$ | 18 | 71 | 51 | $T_2P_2$ | 21 |
| 68 | | $T_2P_2$ | 22 | 72 | | $T_1P_2$ | 23 |
| 69 | | $T_1P_1$ | 16 | 73 | | $T_2P_1$ | 13 |
| 70 | | $T_2P_1$ | 17 | 74 | | $T_1P_2$ | 24 |
| 75 | 51 | $T_1P_1$ | 19 | 79 | 51 | $T_1P_1$ | 22 |
| 76 | | $T_1P_2$ | 21 | 80 | | $T_2P_1$ | 21 |
| 77 | | $T_2P_2$ | 22 | 81 | | $T_2P_1$ | 19 |
| 78 | | $T_1P_2$ | 22 | 82 | | $T_2P_2$ | 25 |

ES
Training Runs

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 1 | 38 | $T_1P_1$ | 27 | 5 | 42 | $T_1P_2$ | 25 |
| 2 | 38 | $T_2P_1$ | 26 | 6 | 42 | $T_2P_2$ | 24 |
| 3 | 38 | $T_1P_1$ | 27 | 7 | 42 | $T_2P_1$ | 16 |
| 4 | 42 | $T_1P_2$ | 22 | 8 | 42 | $T_2P_2$ | 28 |
| 9 | 42 | $T_1P_1$ | 23 | 13 | 47 | $T_1P_2$ | 18 |
| 10 | 47 | $T_2P_1$ | 7 | 14 | 47 | $T_2P_1$ | 12 |
| 11 | 47 | $T_2P_2$ | 17 | 15 | 47 | $T_1P_2$ | 26 |
| 12 | 47 | $T_1P_1$ | 5 | 16 | 47 | $T_2P_2$ | 23 |
| 17 | 49 | $T_1P_1$ | 4 | 21 | 49 | $T_2P_1$ | 11 |
| 18 | 49 | $T_2P_2$ | 18 | 22 | 49 | $T_1P_1$ | 10 |
| 19 | 49 | $T_2P_1$ | 14 | 23 | 49 | $T_1P_2$ | 27 |
| 20 | 49 | $T_1P_2$ | 20 | 24 | 49 | $T_2P_2$ | 20 |
| 25 | 49 | $T_1P_1$ | 11 | 29 | 49 | $T_1P_2$ | 22 |
| 26 | 49 | $T_2P_2$ | 18 | 30 | | $T_1P_2$ | 16 |
| 27 | 49 | $T_2P_2$ | 17 | 31 | | $T_2P_1$ | 11 |
| 28 | 49 | $T_1P_1$ | 12 | 32 | | $T_2P_1$ | 15 |
| 33 | 49 | $T_2P_1$ | 8 | 37 | 49 | $T_1P_2$ | 18 |
| 34 | 49 | $T_2P_1$ | 14 | 38 | | $T_2P_2$ | 19 |
| 35 | 49 | $T_1P_1$ | 9 | 39 | | $T_2P_2$ | 21 |
| 36 | 49 | $T_1P_1$ | 8 | 40 | | $T_1P_2$ | 13 |

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 41 | 49 | $T_1P_2$ | 19 | 45 | 49 | $T_2P_1$ | 25 |
| 42 | | $T_2P_2$ | 18 | 46 | | $T_1P_1$ | 17 |
| 43 | | $T_2P_2$ | 13 | 47 | | $T_1P_1$ | 13 |
| 44 | | $T_1P_2$ | 17 | 48 | | $T_2P_1$ | 16 |

Experimental Runs

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 49 | 49 | $T_1P_1$ | 16 | 53 | 49 | $T_2P_2$ | 24 |
| 50 | | $T_2P_1$ | 21 | 54 | | $T_1P_2$ | 23 |
| 51 | | $T_2P_1$ | 11 | 55 | | $T_2P_2$ | 23 |
| 52 | | $T_1P_2$ | 20 | 56 | | $T_1P_1$ | 16 |
| 57 | 49 | $T_1P_2$ | 24 | 61 | 49 | $T_2P_1$ | 21 |
| 58 | | $T_2P_2$ | 22 | 62 | | $T_2P_2$ | 22 |
| 59 | | $T_2P_1$ | 20 | 63 | | $T_1P_1$ | 11 |
| 60 | | $T_1P_2$ | 16 | 64 | | $T_1P_1$ | 21 |
| 65 | 49 | $T_1P_2$ | 21 | 69 | 49 | $T_1P_1$ | 10 |
| 66 | | $T_1P_2$ | 22 | 70 | | $T_2P_2$ | 23 |
| 67 | | $T_2P_2$ | 70 | 71 | | $T_2P_1$ | 13 |
| 68 | | $T_2P_1$ | 11 | 72 | | $T_1P_1$ | 11 |
| 73 | 49 | $T_2P_2$ | 19 | 77 | 49 | $T_2P_2$ | 23 |
| 74 | | $T_1P_2$ | 21 | 78 | | $T_1P_1$ | 12 |
| 75 | | $T_1P_1$ | 11 | 79 | | $T_2P_1$ | 10 |
| 76 | | $T_1P_2$ | 23 | 80 | | $T_2P_1$ | 20 |
| 81 | 49 | $T_2P_2$ | 21 | 85 | 49 | $T_1P_2$ | 18 |
| 82 | | $T_2P_2$ | 17 | 86 | | $T_2P_1$ | 10 |
| 83 | | $T_2P_1$ | 9 | 87 | | $T_1P_1$ | 11 |
| 84 | | $T_1P_2$ | 20 | 88 | | $T_1P_1$ | 14 |

BY

Training Runs

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 1 | 47 | $T_1P_1$ | 4 | 5 | 42 | $T_1P_1$ | 17 |
| 2 | 42 | $T_1P_1$ | 22 | 6 | 42 | $T_2P_2$ | 20 |
| 3 | 42 | $T_2P_1$ | 20 | 7 | 42 | $T_2P_1$ | 21 |
| 4 | 42 | $T_1P_2$ | 21 | 8 | 42 | $T_1P_2$ | 25 |

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 9 | 42 | $T_1P_2$ | 19 | 13 | 47 | $T_1P_2$ | 15 |
| 10 | 42 | $T_2P_2$ | 27 | 14 | 47 | $T_2P_1$ | 17 |
| 11 | 42 | $T_2P_2$ | 26 | 15 | 47 | $T_1P_1$ | 15 |
| 12 | 47 | $T_2P_2$ | 18 | 16 | 47 | $T_2P_1$ | 23 |
| 17 | 47 | $T_1P_2$ | 20 | 21 | 49 | $T_2P_2$ | 23 |
| 18 | 47 | $T_2P_2$ | 18 | 22 | 49 | $T_1P_2$ | 24 |
| 19 | 47 | $T_2P_1$ | 20 | 23 | 49 | $T_2P_1$ | 19 |
| 20 | 47 | $T_1P_1$ | 14 | 24 | 49 | $T_1P_1$ | 26 |
| 25 | 51 | $T_1P_2$ | 14 | 29 | 51 | $T_2P_1$ | 13 |
| 26 | 51 | $T_1P_1$ | 15 | 30 | 51 | $T_2P_2$ | 13 |
| 27 | 51 | $T_1P_2$ | 10 | 31 | 51 | $T_2P_2$ | 10 |
| 28 | 51 | $T_1P_1$ | 14 | 32 | 51 | $T_2P_1$ | 10 |
| 33 | 49 | $T_1P_2$ | 17 | 37 | 49 | $T_2P_2$ | 26 |
| 34 | 49 | $T_2P_1$ | 20 | 38 | 49 | $T_1P_1$ | 24 |
| 35 | 49 | $T_2P_1$ | 19 | 39 | 49 | $T_1P_2$ | 28 |
| 36 | 49 | $T_2P_2$ | 15 | 40 | 49 | $T_1P_2$ | 22 |
| 41 | 50 | $T_1P_2$ | 18 | 45 | 50 | $T_2P_2$ | 18 |
| 42 | 50 | $T_2P_1$ | 16 | 46 | 50 | $T_2P_1$ | 19 |
| 43 | 50 | $T_1P_1$ | 17 | 47 | 50 | $T_2P_2$ | 21 |
| 44 | 50 | $T_1P_2$ | 21 | 48 | 50 | $T_1P_1$ | 21 |
| 49 | 50 | $T_1P_1$ | 14 | 53 | 50 | $T_1P_2$ | 20 |
| 50 | 50 | $T_2P_2$ | 14 | 54 | 50 | $T_2P_1$ | 21 |
| 51 | 50 | $T_2P_1$ | 15 | 55 | 50 | $T_1P_1$ | 20 |
| 52 | 50 | $T_2P_2$ | 12 | 56 | 50 | $T_1P_2$ | 19 |
| 57 | 50 | $T_2P_2$ | 19 | 61 | 50 | $T_1P_1$ | 19 |
| 58 | 50 | $T_1P_2$ | 24 | 62 | 50 | $T_2P_1$ | 26 |
| 59 | 50 | $T_1P_1$ | 17 | 63 | 50 | $T_2P_2$ | 19 |
| 60 | 50 | $T_1P_2$ | 19 | 64 | 50 | $T_2P_1$ | 23 |

Experimental Runs

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 65 | 50 | $T_1P_2$ | 12 | 69 | 50 | $T_1P_1$ | 11 |
| 66 | 50 | $T_2P_2$ | 19 | 70 | 50 | $T_1P_1$ | 14 |
| 67 | 50 | $T_1P_2$ | 13 | 71 | 50 | $T_2P_1$ | 18 |
| 68 | 50 | $T_2P_2$ | 20 | 72 | 50 | $T_2P_1$ | 17 |
| 73 | 50 | $T_2P_1$ | 14 | 77 | 50 | $T_2P_1$ | 14 |
| 74 | 50 | $T_2P_2$ | 15 | 78 | 50 | $T_1P_1$ | 22 |
| 75 | 50 | $T_1P_1$ | 13 | 79 | 50 | $T_1P_2$ | 17 |
| 76 | 50 | $T_2P_2$ | 14 | 80 | 50 | $T_1P_2$ | 16 |

| Run No. | Aperture | Cond. | No. corr. | Run No. | Aperture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 81 | 50 | $T_1P_2$ | 15 | 85 | 50 | $T_1P_1$ | 16 |
| 82 | 50 | $T_2P_1$ | 14 | 86 | 50 | $T_2P_2$ | 11 |
| 83 | 50 | $T_1P_2$ | 17 | 87 | 50 | $T_2P_2$ | 16 |
| 84 | 50 | $T_2P_1$ | 19 | 88 | 50 | $T_1P_1$ | 15 |
| 89 | 50 | $T_2P_1$ | 19 | 93 | 50 | $T_2P_1$ | 16 |
| 90 | 50 | $T_1P_2$ | 19 | 94 | 50 | $T_1P_1$ | 23 |
| 91 | 50 | $T_1P_2$ | 14 | 95 | 50 | $T_2P_2$ | 18 |
| 92 | 50 | $T_1P_1$ | 16 | 96 | 50 | $T_2P_2$ | 19 |
| 97 | 50 | $T_2P_2$ | 19 | 101 | 50 | $T_1P_2$ | 18 |
| 98 | 50 | $T_1P_2$ | 18 | 102 | 50 | $T_1P_1$ | 19 |
| 99 | 50 | $T_2P_2$ | 14 | 103 | 50 | $T_2P_1$ | 21 |
| 100 | 50 | $T_2P_1$ | 19 | 104 | 50 | $T_1P_1$ | 22 |

<u>JG</u>

Training Runs

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 42 | $T_1P_1$ | 12 | 5 | 47 | $T_2P_1$ | 9 |
| 2 | | $T_2P_1$ | 20 | 6 | | $T_1P_2$ | 19 |
| 3 | | $T_2P_2$ | 27 | 7 | | $T_1P_1$ | 11 |
| 4 | | $T_1P_2$ | 29 | 8 | | $T_2P_2$ | 23 |
| 9 | 47 | $T_2P_1$ | 16 | 13 | 49 | $T_1P_1$ | 20 |
| 10 | | $T_1P_1$ | 27 | 14 | | $T_2P_2$ | 29 |
| 11 | 49 | $T_1P_2$ | 25 | 15 | | $T_1P_1$ | 18 |
| 12 | | $T_2P_2$ | 26 | 16 | | $T_2P_1$ | 18 |
| 17 | 51 | $T_1P_2$ | 18 | 21 | 49 | $T_2P_1$ | 23 |
| 18 | | $T_2P_1$ | 15 | 22 | | $T_2P_2$ | 27 |
| 19 | | $T_2P_2$ | 12 | 23 | | $T_1P_2$ | 26 |
| 20 | | $T_1P_1$ | 7 | 24 | | $T_1P_1$ | 22 |
| 25 | 49 | $T_2P_1$ | 15 | 29 | 49 | $T_1P_2$ | 29 |
| 26 | 49 | $T_2P_2$ | 23 | 30 | 47 | $T_2P_1$ | 22 |
| 27 | 49 | $T_1P_1$ | 22 | 31 | 49 | $T_1P_2$ | 25 |
| 28 | 49 | $T_1P_1$ | 26 | 32 | 49 | $T_2P_2$ | 22 |
| 33 | 50 | $T_2P_1$ | 22 | 37 | 50 | $T_1P_1$ | 20 |
| 34 | | $T_1P_1$ | 20 | 38 | | $T_2P_1$ | 22 |
| 35 | | $T_1P_2$ | 25 | 39 | | $T_2P_2$ | 22 |
| 36 | | $T_1P_2$ | 22 | 40 | | $T_2P_2$ | 26 |

| Run No. | Aperture | Cond. | No. corr. | Run No. | Aperture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 41 | 50 | $T_1P_1$ | 15 | 45 | 50 | $T_2P_1$ | 18 |
| 42 | | $T_2P_1$ | 14 | 46 | | $T_1P_2$ | 24 |
| 43 | | $T_1P_2$ | 20 | 47 | | $T_2P_2$ | 24 |
| 44 | | $T_2P_2$ | 14 | 48 | | $T_1P_1$ | 22 |

Experimental Runs

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 49 | 50 | $T_1P_1$ | 22 | 53 | 50 | $T_2P_1$ | 25 |
| 50 | | $T_1P_2$ | 24 | 54 | | $T_1P_1$ | 23 |
| 51 | | $T_2P_1$ | 15 | 55 | | $T_1P_2$ | 25 |
| 52 | | $T_1P_2$ | 27 | 56 | | $T_2P_2$ | 27 |
| 57 | 50 | $T_2P_1$ | 26 | 61 | 50 | $T_2P_2$ | 23 |
| 58 | | $T_1P_1$ | 22 | 62 | | $T_1P_2$ | 25 |
| 59 | | $T_1P_2$ | 26 | 63 | | $T_2P_2$ | 26 |
| 60 | | $T_2P_1$ | 23 | 64 | | $T_1P_1$ | 24 |
| 65 | 51 | $T_1P_1$ | 15 | 69 | 51 | $T_1P_2$ | 18 |
| 66 | | $T_2P_2$ | 16 | 70 | | $T_2P_1$ | 19 |
| 67 | | $T_1P_2$ | 15 | 71 | | $T_1P_1$ | 15 |
| 68 | | $T_2P_2$ | 13 | 72 | | $T_2P_1$ | 11 |
| 73 | 51 | $T_2P_2$ | 22 | 77 | 51 | $T_2P_1$ | 21 |
| 74 | | $T_1P_1$ | 17 | 78 | | $T_1P_2$ | 20 |
| 75 | | $T_2P_1$ | 19 | 79 | | $T_2P_2$ | 18 |
| 76 | | $T_1P_2$ | 18 | 80 | | $T_1P_1$ | 24 |
| 81 | 51 | $T_1P_2$ | 22 | 85 | 51 | $T_2P_2$ | 21 |
| 82 | | $T_1P_1$ | 20 | 86 | | $T_2P_1$ | 18 |
| 83 | | $T_2P_2$ | 22 | 87 | | $T_1P_1$ | 15 |
| 84 | | $T_2P_1$ | 18 | 88 | | $T_1P_2$ | 22 |

MB Training Runs

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 47 | $T_1P_1$ | 19 | 5 | 47 | $T_1P_1$ | 17 |
| 2 | 47 | $T_2P_1$ | 21 | 6 | 47 | $T_1P_2$ | 25 |
| 3 | 47 | $T_1P_2$ | 14 | 7 | 47 | $T_2P_1$ | 20 |
| 4 | 47 | $T_2P_2$ | 18 | 8 | 47 | $T_1P_1$ | 18 |
| 9 | 47 | $T_2P_2$ | 26 | 13 | 49 | $T_1P_2$ | 20 |
| 10 | 47 | $T_1P_2$ | 22 | 14 | 49 | $T_2P_2$ | 27 |
| 11 | 47 | $T_2P_1$ | 25 | 15 | 49 | $T_2P_2$ | 23 |
| 12 | 49 | $T_2P_1$ | 20 | 16 | 49 | $T_1P_2$ | 21 |

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr |
|---|---|---|---|---|---|---|---|
| 17 | 49 | $T_2P_1$ | 22 | 21 | 51 | $T_1P_1$ | 18 |
| 18 | 51 | $T_2P_2$ | 17 | 22 | 51 | $T_2P_1$ | 18 |
| 19 | 51 | $T_1P_1$ | 10 | 23 | 51 | $T_1P_2$ | 19 |
| 20 | 51 | $T_2P_1$ | 13 | 24 | 51 | $T_2P_2$ | 15 |
| 25 | 51 | $T_2P_1$ | 14 | 29 | 51 | $T_1P_2$ | 14 |
| 26 | 51 | $T_1P_2$ | 19 | 30 | 51 | $T_1P_1$ | 16 |
| 27 | 51 | $T_1P_1$ | 12 | 31 | 51 | $T_2P_2$ | 11 |
| 28 | 51 | $T_2P_1$ | 13 | 22 | 51 | $T_2P_2$ | 13 |
| 33 | 49 | $T_1P_1$ | 21 | 37 | 49 | $T_1P_1$ | 21 |
| 34 | | $T_2P_2$ | 25 | 38 | | $T_2P_1$ | 23 |
| 35 | | $T_2P_2$ | 26 | 39 | | $T_1P_2$ | 22 |
| 36 | | $T_1P_2$ | 25 | 40 | | $T_2P_1$ | 23 |
| 41 | 50 | $T_2P_2$ | 25 | 45 | 50 | $T_1P_1$ | 20 |
| 42 | | $T_2P_1$ | 22 | 46 | | $T_1P_2$ | 23 |
| 43 | | $T_2P_1$ | 25 | 47 | | $T_1P_2$ | 25 |
| 44 | | $T_1P_1$ | 24 | 48 | | $T_2P_2$ | 23 |
| 49 | 50 | $T_1P_2$ | 24 | 53 | 50 | $T_2P_2$ | 28 |
| 50 | | $T_1P_1$ | 27 | 54 | | $T_1P_1$ | 22 |
| 51 | | $T_2P_1$ | 23 | 55 | | $T_1P_2$ | 27 |
| 52 | | $T_2P_2$ | 29 | 56 | | Void | |

Experimental Runs

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr |
|---|---|---|---|---|---|---|---|
| 57 | 50 | $T_2P_2$ | 18 | 61 | 50 | $T_2P_2$ | 19 |
| 58 | | $T_1P_2$ | 18 | 62 | | $T_2P_1$ | 25 |
| 59 | | $T_1P_1$ | 17 | 63 | | $T_1P_1$ | 19 |
| 60 | | $T_2P_1$ | 18 | 64 | | $T_1P_2$ | 22 |
| 65 | 50 | $T_1P_2$ | 23 | 69 | 50 | $T_1P_1$ | 15 |
| 66 | | $T_1P_1$ | 21 | 70 | | $T_2P_2$ | 21 |
| 67 | | $T_2P_2$ | 24 | 71 | | $T_2P_1$ | 14 |
| 68 | | $T_2P_1$ | 19 | 72 | | $T_1P_2$ | 17 |
| 73 | 50 | $T_1P_2$ | 21 | 77 | 50 | $T_2P_2$ | 26 |
| 74 | | $T_2P_2$ | 26 | 78 | | $T_2P_1$ | 22 |
| 75 | | $T_1P_1$ | 23 | 79 | | $T_2P_1$ | 23 |
| 76 | | $T_1P_2$ | 21 | 80 | | $T_1P_1$ | 25 |

| Run No. | Aper-ture | Cond. | No. corr. | Run No. | Aper-ture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 81 | 50 | $T_1P_1$ | 20 | 85 | 50 | $T_2P_2$ | 28 |
| 82 | | $T_1P_1$ | 28 | 86 | | $T_1P_2$ | 28 |
| 83 | | $T_2P_1$ | 15 | 87 | | $T_2P_1$ | 23 |
| 84 | | $T_2P_2$ | 18 | 88 | | $T_1P_2$ | 25 |
| 89 | 50 | $T_1P_2$ | 21 | 93 | 50 | $T_1P_2$ | 20 |
| 90 | | $T_1P_1$ | 17 | 94 | | $T_2P_2$ | 21 |
| 91 | | $T_2P_2$ | 23 | 95 | | $T_2P_1$ | 23 |
| 92 | | $T_1P_1$ | 16 | 96 | | $T_2P_1$ | 20 |

HG
Training Runs

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 38 | $T_1P_1$ | 8 | 4 | 38 | $T_2P_1$ | 14 |
| 2 | | $T_1P_2$ | 30 | 5 | | $T_2P_2$ | 28 |
| 3 | | $T_1P_1$ | 18 | 6 | | $T_1P_1$ | 17 |
| 7 | 42 | $T_2P_1$ | 14 | 10 | 42 | $T_2P_2$ | 15 |
| 8 | | $T_1P_2$ | 21 | 11 | | $T_1P_2$ | 23 |
| 9 | | $T_2P_2$ | 17 | 12 | | $T_2P_1$ | 10 |
| 13 | 42 | $T_1P_1$ | 13 | 17 | 42 | $T_1P_1$ | 14 |
| 14 | | $T_2P_2$ | 15 | 18 | | $T_2P_1$ | 10 |
| 15 | | $T_2P_1$ | 8 | 19 | | $T_2P_2$ | 21 |
| 16 | | $T_1P_2$ | 16 | 20 | | $T_1P_2$ | 20 |
| 21 | 42 | $T_2P_2$ | 17 | 25 | 42 | $T_1P_2$ | 20 |
| 22 | | $T_2P_1$ | 12 | 26 | | $T_2P_1$ | 14 |
| 23 | | $T_1P_2$ | 20 | 27 | | $T_2P_2$ | 23 |
| 24 | | $T_1P_1$ | 15 | 28 | | $T_1P_1$ | 13 |
| 29 | 42 | $T_2P_2$ | 16 | 33 | 42 | $T_2P_2$ | 26 |
| 30 | | $T_2P_1$ | 12 | 34 | | $T_1P_1$ | 19 |
| 31 | | $T_1P_2$ | 25 | 35 | | $T_2P_1$ | 19 |
| 32 | | $T_1P_1$ | 17 | 36 | | $T_1P_2$ | 23 |
| 37 | 42 | $T_1P_2$ | 18 | 41 | 42 | $T_2P_1$ | 25 |
| 38 | | $T_2P_2$ | 22 | 42 | | $T_1P_1$ | 23 |
| 39 | | $T_2P_2$ | 24 | 43 | | $T_1P_2$ | 24 |
| 40 | | $T_2P_1$ | 13 | 44 | | $T_1P_1$ | 21 |

| Run No. | Aperture | Cond. | No. corr. | Run No. | Aperture | Cond. | No. corr. |
|---|---|---|---|---|---|---|---|
| 45 | 42 | $T_2P_2$ | 25 | 49 | 42 | $T_1P_2$ | 25 |
| 46 | | $T_1P_1$ | 15 | 50 | | $T_1P_2$ | 27 |
| 47 | | $T_1P_1$ | 17 | 51 | | $T_2P_1$ | 21 |
| 48 | | $T_2P_2$ | 26 | 52 | | $T_2P_1$ | 23 |
| 53 | 47 | $T_2P_2$ | 18 | 57 | 47 | $T_1P_1$ | 11 |
| 54 | | $T_2P_2$ | 18 | 58 | | $T_2P_1$ | 13 |
| 55 | | $T_1P_2$ | 18 | 59 | | $T_1P_1$ | 13 |
| 56 | | $T_1P_2$ | 20 | 60 | | $T_2P_1$ | 10 |
| | | | Experimental Runs | | | | |
| 61 | 47 | $T_2P_1$ | 6 | 65 | 47 | $T_1P_2$ | 21 |
| 62 | | $T_2P_1$ | 10 | 66 | | $T_1P_2$ | 18 |
| 63 | | $T_2P_2$ | 13 | 67 | | $T_1P_1$ | 12 |
| 64 | | $T_2P_2$ | 19 | 68 | | $T_1P_1$ | 10 |
| 69 | 47 | $T_2P_2$ | 15 | 73 | 47 | $T_1P_1$ | 16 |
| 70 | | $T_2P_2$ | 16 | 74 | | $T_1P_2$ | 23 |
| 71 | | $T_2P_1$ | 10 | 75 | | $T_1P_2$ | 20 |
| 72 | | $T_1P_1$ | 12 | 76 | | $T_2P_1$ | 17 |
| 77 | 47 | $T_1P_2$ | 14 | 81 | 47 | $T_1P_1$ | 12 |
| 78 | | $T_2P_2$ | 18 | 82 | | $T_2P_2$ | 15 |
| 79 | | $T_1P_1$ | 6 | 83 | | $T_1P_2$ | 13 |
| 80 | | $T_2P_1$ | 12 | 84 | | $T_2P_1$ | 7 |
| 85 | 47 | $T_2P_1$ | 6 | 89 | 47 | $T_1P_2$ | 19 |
| 86 | | $T_1P_2$ | 10 | 90 | | $T_2P_2$ | 20 |
| 87 | | $T_2P_1$ | 11 | 91 | | $T_1P_1$ | 11 |
| 88 | | $T_2P_2$ | 15 | 92 | | $T_1P_1$ | 13 |
| 93 | 47 | $T_2P_2$ | 20 | 97 | 47 | $T_1P_1$ | 14 |
| 94 | | $T_2P_1$ | 7 | 98 | | $T_1P_2$ | 16 |
| 95 | | $T_2P_1$ | 12 | 99 | | $T_2P_2$ | 10 |
| 96 | | $T_1P_1$ | 13 | 100 | | $T_1P_2$ | 16 |